Mind the gap: new developments and outlook for China's transport sector to 2030

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Abstract

Since 2000, China has experienced a 7-fold increase in passenger vehicles and 4-fold increase in freight turnover and the government is placing greater policy emphasis on its rapidly expanding transport sector. Over the next twenty years, China's transportation energy use is expected to significantly increase from its current 10 % share of national energy consumption. To help slow this unprecedented import-dependent growth in transport demand for oil, China has adopted more stringent fuel economy standards to improve passenger and freight vehicle efficiency, promoted natural gas vehicles and established pilot subsidy programs for high efficiency, plug-in hybrid and electric vehicles. However, it is unclear how much these policies will contribute to the national energy efficiency and CO_2 reduction targets and to reducing the growth in oil use.

This paper begins by reviewing the progress and challenges of China's most recent transport policies – particularly its hybrid and electric vehicle pilot subsidy program – and the latest transport fleet developments through 2013. On the basis of these recent developments, we developed a comprehensive, technology and end-use based energy demand and CO_2 emission outlook of China's passenger and freight transport and used it to evaluate the impact of transport efficiency and fuel switching on China's growing domestic oil and gas supply-demand gap. We find that a fast-growing transport sector will more than double demand for oil and will constitute an important component to the growth of national energy demand, despite significant efficiency improvements, electrification and growing shares of natural gas vehicles. Surprisingly, freight road transport – and not private passenger transport – will be the largest driver of future transport energy demand, with heavy-duty trucks alone consuming more energy than all passenger vehicles by 2030. These results suggest that more policies are needed to address freight transport energy use, as an alternative scenario of more aggressive electrification, diesel to natural gas switch for heavy-duty trucks and improved logistics can displace 21 % of annual diesel consumption by 2030.

Introduction

Following the precedent set under the 11th Five-Year Plan (FYP) for national development for 2006 to 2010, China's 12th FYP included overarching national 2015 targets for energy conservation, including 16 % reduction in energy consumption per unit of GDP and 17 % reduction in CO_2 emissions per unit of GDP from 2010 levels. While significant energy efficiency efforts were undertaken for the buildings and industrial sectors under the 11th FYP, national policies to promote energy conservation and efficiency were not introduced for the transport sector until 2010. Although the transport sector only accounted for 10 % of national energy consumption in 2012, growth in this sector has been unprecedented and driven by a 7-fold increase in passenger vehicles and 4-fold increase in freight turnover in China since 2000.

Driven by economic growth and rising average income levels, China's passenger transport sector is undergoing significant transformations in recent years in terms of total passenger turnover, fleet composition and vehicle stock and vehicle travel trends. Total passenger turnover in terms of passenger-kilometers travelled grew by 7 % annually from 2000 to 2005, with annual growth accelerated to 10 % annually from 2006 to 2011. In absolute terms, total passenger turnover more than doubled over the last decade from 1,226 billion passenger-kilometers in 2000 to 3,388 billion passenger-kilometers in 2012, with road transport consistently accounting for more than half of all passenger turnover activity (NBS 2013). More specifically, China's total stock of passenger motorized vehicles has undergone a seven-fold increase from 12 million vehicles in 2002 to 89 million vehicles in 2012, with the bulk of growth driven by the expanding total stock of private sedans and sports utility vehicles (SUVs). In 2002, China's stock of private sedans and SUVs were similar in size to commercial vehicles (taxis, public and business fleet vehicles) with 4 million vehicles total. But by 2012, private sedans and SUVs have increased by 17-fold to over 72 million vehicles, compared to only 11 million commercial vehicles (NBS 2013). In relative terms, private sedans and SUVs' share of total passenger vehicle stock increased from 34 % in 2002 to 81 % in 2012 while commercial vehicles' share decreased from 59 % to 14 % during the same period.

The growing dominance of private sedans and SUVs in China's passenger vehicle fleet can be linked to the rapid take-off in private car ownership rates particularly in urban areas in the last five years. While it took six years from 2000 to 2006 for the car ownership rate to reach 5 %, it took only another six years for car ownership rate to grow from 6 % in 2007 to over 21 % in 2012 (NBS, various years). A likely reason for the rapid growth in private car ownership, especially after 2002, is the continual decline of car prices after China entered the World Trade Organization (WTO) in December 2001 (Huo and Wang 2012). Their increased affordability has not only made private sedans and SUVs a growing mode of road transport, but also an increasing status symbol of wealth for urban households. Compared to international car ownership levels of 300 to 500 cars per 1,000 people, or the equivalent of 30 % and 50 %, Chinese car ownership rate are relatively low and have much room to grow.

As a relatively young and emerging market, China's car market is expected to be dominated by new-growth, first vehicle purchases in the near future (Huo and Wang 2012). While car ownership has already grown in megacities in China with some key cities facing government-imposed restrictions due to environmental and congestion concerns, strong demand for private vehicles is expected from the rising number of small and medium-sized cities. Because many of these smaller cities still lack a strong public transit infrastructure or high level of environmental awareness, its urban residents will likely purchase private vehicles not only to meet their mobility needs, but also to seek the social prestige of owning a vehicle. For the increasingly wealthy urbanites, market analysts also expect rising trend of "trading up" where the first, entry-level vehicle is replaced by higher priced, premium luxury vehicle. The societal trends driving strong private vehicle sales and ownership will take time to change, and significant plateauing or reductions in total private vehicle stock is not expected before 2030. As the total stock of China's passenger vehicle fleet has grown within the last decade, the addition of new vehicles to the fleet along with increasingly more stringent fuel economy standards have helped improved the average fleet efficiency.

Similar to passenger transport, China's freight transport activity has also undergone significant growth across all modes since China joined the WTO and the subsequent rapid economic growth and increasing global trade. While freight turnover only increased by 14 % over three years from 2000 to 2003, it has grown by an average growth rate of 13 % per year since 2003. As a result, the total freight turnover of 17.4 billion tonne-kilometer (t-km) in 2012 is nearly four times the total freight turnover of only 4.4 billion t-km in 2000 (NBS 2013). As with passenger transport, road transport has also grown from moving 14 % of total freight turnover in 2000 to 34 % of the total in 2012, making it the second largest mode of freight transport after water. The growing activity in road transport of freight has been met with a growing stock of trucks that has nearly tripled from 12 million in 2002 to 32 million in 2012 (NBS 2013). Most of this growth has been in heavy and light trucks, which together make up 85 % of the total stock of trucks in 2012. In China, freight trucks are operated primarily for commercial purposes and heavy-duty trucks often travel longer distance than light-duty trucks since they are used more often for long-distance travel. While China adopted fuel economy standards for trucks in 2008, their impact on improving the average fuel efficiency of trucks is less profound than that of passenger vehicles because of slower turnover, and overloading and inefficient operation are two key challenges for freight road transport in China.

Given the rising energy security implications of growing transport fuel demand from rapidly growing passenger and freight transport and dependence on imported crude oil, the Chinese government has introduced a mix of energy policies and programs for the transport sector during the 12th FYP period, including mandatory administrative measures, voluntary programs and financial incentives and subsidies. This paper reviews the progress and challenges of China's most recent transport vehicle policies that have influenced developments in China's current transport fleet, particularly its hybrid and electric vehicle pilot subsidy program. On the basis of these recent developments, this paper presents a comprehensive, technology and end-use based energy demand and CO_2 emission outlook of China's passenger and freight transport that is developed and used to evaluate the impact of transport efficiency and fuel switching on China's growing domestic oil and gas supply-demand gap.

In this study, we focused our policy analysis and modelling only on technology-based transport policies and did not attempt to evaluate the potential of transport policies that reduce or shift transport activity to other, non-motorized modes. We excluded other transport policies in this study because while there are local efforts underway to promote mode-shifting and restrict or lower car ownership and usage, the effectiveness of these policies in reducing transport energy consumption and CO_2 emissions have been very limited. For example, some major cities such as Guangzhou have recently introduced a bike-sharing program that is integrated with its bus rapid transit system (BRT) to promote mode shifting, but rider surveys have shown that most of the shift towards BRTs has been away from subways, taxis, walking, and biking, rather than from private vehicle use (ITDP 2011). Our previous study also showed very limited relative energy and emissions reduction impact of policies to expand public transit, discourage private vehicle usage or ownership, and promote mode shifting when compared to vehicle technology-based policies because China's total stock of vehicles is already so large in scale, and expected to continue rising at least through 2030 (Zhou et al. 2013).

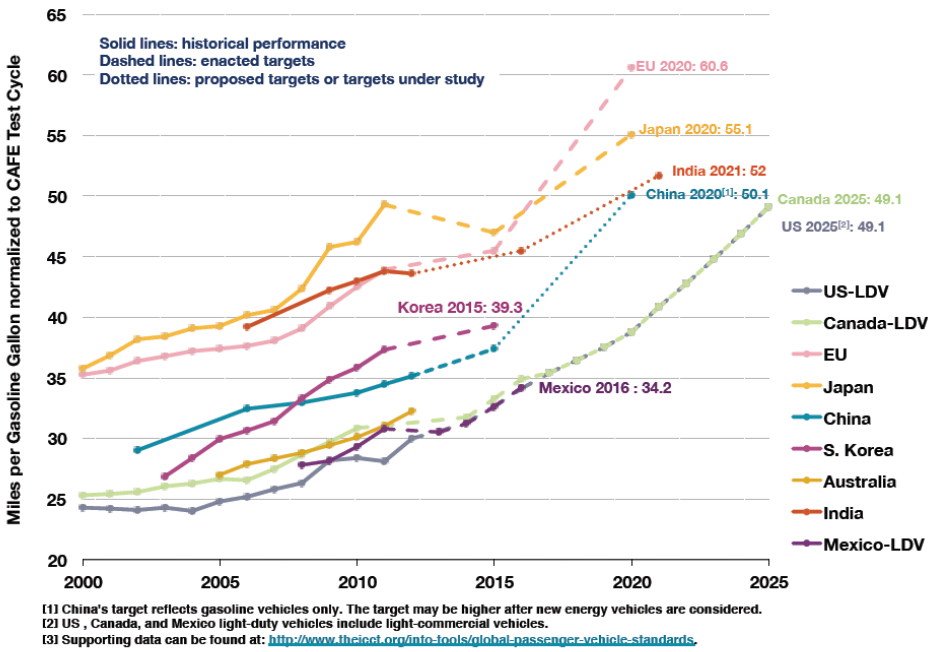

Figure 1. Comparison of Global Passenger Vehicle Fuel Consumption Standards Normalized to European Test Cycle. Source: ICCT 2014.

Recent transport policy developments in China and energy implications

Over the last few years, China has adopted key transport policies that include traditional measures of mandatory fuel economy standards for passenger and freight vehicles, as well as subsidies and incentives for efficient and alternative energy vehicles.

FUEL ECONOMY STANDARDS

China's first national fuel economy standard was implemented in 2005–2006 for passenger vehicles, followed by a second phase in 2008–2009. Unlike the US Corporate Average Fuel Economy (CAFE) standards, which regulate efficiency averaged across the entire fleet of models, China's standard applies to individual vehicles in 16 weight classes, and includes ordinary passenger sedans as well as SUVs and multi-purpose vans.

For the first two phases of the standard, individual vehicles must meet the limit for its given weight class. Data shows that the sales-weighted average fuel consumption rates of Chinese autos decreased by 11.5 % from 9.11 liters per 100 kilometers (L/100 km) in 2002 to 8.06 L/100 km in 2006, coinciding with the implementation of the first phase of China's fuel economy standards (Wang et al. 2010). Phase III of China's national fuel economy standards were announced in August 2009, with phased-in implementation from 2012 to 2015. An overall target of achieving 7 L/100 km for passenger vehicles in 2015 was set, reflecting a shift away from the maximum limits per vehicle approach in Phases I and II towards the corporate average fuel consumption limits across the fleet of models. This shift towards the CAFE approach represents an attempt to address the increasing shift of the Chinese auto market towards larger vehicles with higher allowable fuel consumption limits and the subsequent offset of efficiency gains. The Phase III standard still includes per-vehicle fuel consumption targets for the 16 individual weight bins, but the more stringent achievement of target reduction is measured at a fleet average basis.

Phases II and III of China's fuel economy standards are expected to contribute further reductions to fuel consumption, with estimates of sales-weighted average fuel consumption reaching 7.8 L/100 km in 2009. However, it is also important to recognize that because estimates are often based on laboratory test result following the New European Driving Cycle, real-world fuel consumption may be higher. Previous studies have found that the sales-weighted real world average fuel consumption rates of Chinese autos in 2009 was actually 9.02 L/100 km due to differences between real-world driving conditions (e.g., average speed, acceleration) and the laboratory tested driving cycle (Huo et al. 2011) This 15 % higher differential for real-world driving fuel consumption is similar to the real-world differential that the U.S. Environmental Protection Agency has found for U.S. light-duty vehicles in the past.

In January 2014, the proposed Phase IV fuel economy standards were released for comment and are currently under review, with phased-in implementation expected for 2016 through 2020. The maximum vehicle fuel consumption limits are set at the Phase III levels and the proposed corporate average fleet consumption limit is 25 % to 37 % lower than the maximum (Phase III) limits for each weight bin. Overall, the fleet average target is 5 L/100 km by 2020, or a total reduction of 29 % compared to the 7 L/100 km target for 2015.

Other notable changes in the proposed Phase IV standards include more stringent requirements for heavier vehicles and new credits and flexibilities for meeting the corporate average fleet consumption target with multiplier credits for plug-in hybrid, all electric and fuel cell vehicles, ultra-efficient (e.g., hybrid) vehicles and the installation of innovative efficient technologies (ICCT 2014). As seen in Figure 1, China's Phase III and proposed Phase IV standard make it one of the more stringent standards internationally, with a more stringent 2016 limit than Mexico and more stringent 2020 limits than the U.S.

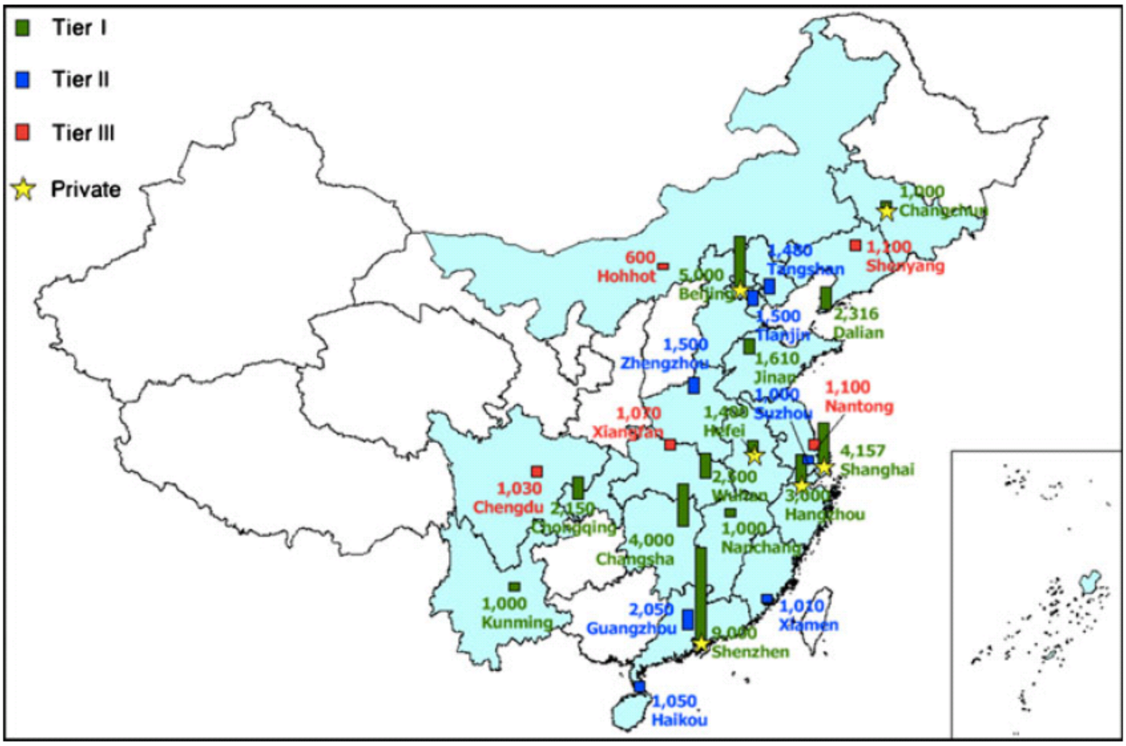

Figure 2. Map of Pilot Cities and their NEV Targets under the 10 Cities, 1,000 Vehicles Program. Source: Gong et al. 2013.

and Canada. It remains below EU and Japan's 2020 targets and slightly below India's 2021 target.

For light-duty commercial vehicles, China adopted a national fuel economy standard in 2007 with phased-in implementation from 2009 to 2011 that also sets the fuel consumption limit based on gross vehicle weight and engine displacement size.

SUBSIDIES FOR HIGH EFFICIENCY VEHICLES

Besides the top-down regulations of fuel economy standards, China has also established subsidies to promote the purchase of efficient vehicles. The energy-saving car subsidy was first established in 2010 and offered a direct reduction of 3,000 yuan per vehicle from the sales price of new cars with engine displacements of less than 1.6 liters that can meet the Phase III corporate average fleet fuel consumption limits for 2015 prior to 2015. The subsidy was renewed in October 2011 with more stringent fuel consumption limits set at 7 % to 8 % lower than the Phase III limits.

In October 2013, the subsidy was renewed again with the minimum fuel consumption requirements for each vehicle weight class further tightened by 2 % to 14 % from the Oct 2011 levels, with greater stringency for heavier vehicles (ICCT 2013). In addition, the 2013 renewal also introduces for the first time a tailpipe emissions requirement requiring vehicles with less than 1.6 liters engines to meet the new China light-duty vehicle emission standards released in September 2013 to qualify for the subsidy.

In addition to the energy-saving subsidy, China initiated a scrappage program in 2009 to accelerate the retirement of old, inefficient cars. This program provides rebates of 450 to 900 USD[1] to consumers who trade in their old, heavily polluting cars and light-duty trucks that fail to meet the "Euro I" tailpipe emissions standards for new vehicles (Huo and Wang 2012). The rebates were doubled or tripled depending on vehicle types in 2010.

NEW ENERGY VEHICLE DEPLOYMENT: DEMONSTRATIONS AND SUBSIDIES

In addition to efforts to improve the overall efficiency of motor vehicles, the Chinese government also began actively promoting the development of electric and other new energy vehicles in the last decade. Since 2005, Chinese policies have emphasized commercializing new energy vehicles with the setting of fleet and sales targets with complementary financial incentives for "new energy vehicles (NEV)" that are officially defined as hybrid electric vehicles (HEV), battery electric vehicles (EV), fuel cell vehicles (FCV) and hydrogen internal combustion vehicles in 2007.

10 Cities, 1,000 Vehicles Demonstration Program

A major component of the recent push for NEV deployment, particularly in public fleets, is the 10 Cities, 1,000 Vehicles program established initially by the Ministry of Science and Technology (MOST) and the Ministry of Finance (MOF) in January 2009. As a demonstration program for HEVs, EVs and FCVs, the 10 Cities, 1,000 Vehicles program called for pilot cities to initially introduce 1,000 NEVs every year for three years in their municipal public service vehicle fleets (e.g., taxis, buses, and municipal government vehicles). The number of pilot cities expanded from the initial 13 cities chosen to a total of 25 cities by 2010, with 6 major cities out of the 25 chosen to launch additional pilots to subsidize private purchases of plug-in hybrid vehicles and all electric vehicles. Figure 2 shows a map of the 25 pilot cities and the NEV targets set for their municipal fleets and/or private fleets for 2012.

1. In 2009, 1 USD = 0.748 Euros = 7.115 RMB.

As participants in the program, the pilot cities are eligible to receive national and local subsides for purchasing NEVs (including both passenger cars and buses) for their municipal fleets. The central government provides subsidies to cover the NEV's higher purchase costs, including 4,000 to 50,000 RMB for plug-in hybrids; 60,000 RMB for EVs; and 250,000 RMB for FCV (Gong et al. 2013). For plug-in hybrids, the subsidy amount is a function of the vehicle's electric power ratio and energy-saving level. In addition, local governments in the pilot cities are expected to not only provide financial support to help partially cover the higher purchase costs, but also in infrastructure development and vehicle maintenance.

By August 2011, the average progress of the 25 cities towards meeting their NEV targets was only at 26 %, with a large variation in the progress of different cities towards their 2012 target (Gong et al. 2013). Pilot cities that were part of the program as early as 2009 ("Tier I" cities) such as Shanghai, Hangzhou and Chongqing were further along towards their NEV targets while some of the smaller and later participating Tier II and Tier III cities such as Xiangfan and Shenyang had met less than 5 % of their NEV target. By the end of 2012, only 7 out of the 25 pilot cities had exceeded the fleet target of 1,000 vehicles but none of the cities had reached 100 % of their municipal fleet target (Marquis et al. 2013).

The pilot cities' slow progress toward meeting their NEV targets and the slow growth in NEV production highlight key market and technological challenges to rapid deployment and commercialization of plug-in hybrid and electric vehicles in China. As with EV markets in other countries, the high cost of NEVs is still a major barrier to greater market adoption and the subsidies offered under the 10 Cities, 1,000 Vehicles are insufficient in covering the higher costs. For example, in the pilot city of Changchun, NEV buses still cost twice as much as conventional buses after receiving the national subsidy (Lo 2014). The high upfront costs of NEVs, as well as the subsequent maintenance costs, make it difficult for local governments – especially those in less developed regions - to purchase for their municipal fleets.

Technology choices and performance is another key obstacle to greater market uptake of NEVs in China. Because the current subsidies do not differentiate between technologies with inferior performance such as lead-acid batteries and those with more advanced technologies such as lithium-ion batteries, more advanced NEV technologies have not benefited from the financial support for increasing market deployment. Instead, lead-acid batteries have been used in top-selling EV models because of their lower costs, but have resulted in inferior performance with lower driving range and driving speed. Due to immature technologies with poor performance, the Northern city of Changchun had to abandon its electric-only buses because its batteries were not able to perform under severe cold winter conditions (Lo 2014). In addition, the current heavily concentrated NEV production and local protectionism of NEV industries have also limited competitiveness in the industry. In China, the top 5 electric and hybrid car manufacturers account for 99 % of total production and includes 4 domestic Chinese manufacturers as well as a foreign joint-venture manufacturer based in China (Nissan-Zhenzhou). The Chinese carmaker Cherry alone produces 71 % of battery electric cars (Gong et al. 2013). Local governments have also prioritized local NEV makers through favorable local subsidies and fleet purchasing decisions, further limiting competitiveness and greater development of the NEV industry.

In addition to the challenges facing NEV production and sales, shortcomings in EV infrastructure development in China may also contribute to slowing the mass deployment of NEVs, especially to the private fleet. On one hand, standardization of EV technologies has lagged behind the pace of technology development. MIIT standards to align all EV charging components were issued only in 2010, and there is still no national standard yet for EVs. Local participation in EV infrastructure development has also remained low, with only 168 charging stations built in the 25 pilot cities in 2011 to support fleet charging (Gong et al. 2013). There is some recent progress to expand EV infrastructure, but it is unclear if the pace of development will be enough to stimulate market uptake of EVs. To address future demand from private EV owners, the State Grid is planning to build 10,000 charging stations and 500,000 charging piles/poles by 2020 with 32.3 billion RMB investment (Tagscherer 2012).

2012 Development Plan for New Energy Vehicles and New Subsidies

In light of the challenges facing the demonstrations of EV deployment in municipal fleets, the State Council issued a *Development Plan for Fuel Efficient and New Energy Vehicles* in 2012. This plan sets new national targets for the production of NEVs, including the production of 500,000 plug-in hybrid and EVs by 2015 and 2 million by 2020. It also sets a cumulative production and sales target of more than 5 million NEVs over that time period.

In alignment with the goals and policy directions set out under the 2012 *Development Plan for Fuel-Efficient and New Energy Vehicles*, the NEV subsidies introduced under the 10 Cities, 1,000 Vehicles program were renewed and refined in September 2013. In particular, to qualify for the NEV subsidy, participating cities must now meet new detailed requirements that have been developed to correct some of the issues with the old program. First, the new subsidy requires local EV fleets to meet deployment targets of 5,000 NEVs for smaller cities and 10,000 NEVs for mega cities from 2013 to 2015. These cities must also limit the share of NEVs manufactured locally to 70 % or less to mitigate local protectionism and 30 % of all new public vehicle purchases must be NEVs (ICCT 2013). Participating pilot cities must also provide detailed local incentive policies for NEV purchase and fleet operation as well as feasible plans for infrastructure construction. Another major change with the subsidy renewal is the adoption of more straightforward and simpler criteria for setting the subsidy levels, which is now based on all-electric ranges for PHEVs and HEVs and vehicle length for buses.

Slow sales of only 17,642 NEVs in 2013 have led the government to both expand the subsidy program and to increase the subsidy levels (Xinhua 2014). The subsidy program was expanded to a total of 40 cities and a statement was issued in February 2014 assuring extension of the subsidy past 2015. In addition, the subsidy amounts for 2014 and 2015 were also revised upwards, suggesting that China is still struggling to accelerate mass NEV deployment and that policy support for electrification will remain important in the near-term.

China's transport outlook: Modelling methodology

In order to evaluate the Chinese transport sector's future energy demand, particularly for oil and oil products, and to evaluate the gap between demand and domestic supply, the bottom-up, sector-based China Energy End-Use Model is used to characterize macroeconomic and physical drivers of transport energy consumption. The model uses an accounting framework in the LEAP software platform developed by the Stockholm Environment Institute. Our China Energy End-Use Model captures the diffusion of end-use technologies and macroeconomic and sector-specific drivers of energy demand in four key economic sectors: residential buildings, commercial buildings, transport and industry. On the energy supply and transformation side, the model also considers resource supply curves and captures the energy required to extract fossil fuels and produce energy. The model also features a power sector module with distinct and customizable generation dispatch algorithms that can dispatch electricity fuel sources in different orders, such as proportional to demand or prioritizing renewables over fossil fuel generation.

This model enables detailed consideration of technological development - vehicle ownership, vehicle-specific efficiency improvements, and transport electrification - as a way to evaluate China's energy and emission reduction development path from a bottom-up perspective. Key drivers of transport energy use in the model include activity drivers (e.g., total population growth, urbanization, vehicle stock), economic drivers (e.g., total GDP, value-added GDP, income), energy intensity trends (energy intensity of different vehicle types), and carbon intensity trends. These factors are in turn driven by changes in consumer preferences, settlement and infrastructure patterns, technical change, and overall economic conditions. Key macroeconomic parameters such as economic growth, population, and urbanization are aligned with international sources (e.g., the United Nations World Population Prospects) as well as Chinese sources (e.g., China Energy Research Institute reports).

Transport sector activity is specifically driven by demand for freight transport and for passenger transport. Freight transport is calculated as a function of economic activity measured by value-added GDP while passenger transport is based on average vehicle-kilometers travelled by mode (e.g., bus, train, car) of moving people.

In the model, freight transport demand is driven by faster economic growth in the earlier years as GDP is expected to continue its recent rapid growth with international trade continuing to play an important role in coming years. In later years, however, road freight growth is slowed to a linear function as the relative importance of foreign trade in GDP is expected to decline.

For passenger transport, growing vehicle-kilometers travelled in different modes is driven by population growth and growing demand for personal transport with rising income levels. The largest mode of passenger transport is road transport, which is driven primarily by the burgeoning ownership of private cars that follows rising per capita income.

Transport energy consumption varies by the mode of transport, type of technologies and the type of mobility services provided. Historical transport data including vehicles stock, average distance travelled and total transport energy consumption by fuel type have been calibrated where possible to the latest national data found in published national statistical yearbooks. More detailed description of the model and its underlying assumptions for future projections and methodologies can be found in Fridley et al. 2012.

In this study, a reference scenario of development is developed as the basis for evaluating China's energy development outlook to 2030. This reference scenario is not intended to represent what would happen in China in the absence of policy intervention (i.e., "Frozen" scenario) or what currently stated Chinese policy goals would achieve (i.e., Business as Usual scenario), but rather is intended to represent a pathway of continuous efficiency improvement. In particular, the reference scenario assumes that the Chinese economy will continue on a path of lowering its energy intensity with efficiency improvements consistent with moderate pace of "market-based" improvement in all sectors. For the transport sector, this translates into meeting the moderate fuel economy improvements in transport fleets as targeted in the proposed fuel economy standards and continued rail electrification following stated goals.

In addition to the reference scenario, an alternative scenario is developed for evaluating potential changes in the transport sector that would reduce China's oil dependence. Specifically, this alternative scenario considers the potential energy (particularly in the form of oil and oil products) savings as well as energy-related CO_2 emissions reductions of four strategies to reduce oil dependence and increase fuel diversification in the transport sector. These four strategies include:

1. Acceleration of light-duty vehicle electrification through more aggressive policies and effective implementation of the New Energy Vehicle development plan in passenger transport
2. Accelerated rail electrification from recent pace in passenger and freight transport
3. Improving logistics to help reduce the existing challenge with overloading and underloading of freight trucks and optimize freight dispatch and routes, resulting in reduced VKT of heavy-duty trucks in freight transport
4. Promoting faster fuel switching from diesel to natural gas for heavy-duty trucks in freight transport

Table 1 compares the key differences in assumptions and modelling parameters between the two transport scenarios.

For both scenarios, the same transport vehicle stock projections are adopted as shown in Table 2.

China 2030 transport energy and emissions outlook and supply-demand gap implications

REFERENCE TRANSPORT SCENARIO RESULTS

China's transport final energy demand is expected to grow steadily from 241 million tonnes of oil equivalent (Mtoe) in 2010 to 427 Mtoe in 2020 and 629 Mtoe in 2030 under the reference scenario of. As expected, the vast majority (96 %) of fuel consumed in the transport sector currently is oil. In the future, oil will continue to dominate transport fuel use with 88 % fuel share by 2030 but fuel diversification is expected with

Table 1. Key transport assumptions for the reference and alternative transport scenario.

	Reference scenario	Alternative transport scenario
Private and Fleet Car Electrification	0 % in 2010 to 7 % in 2030	0 % in 2010 to 20 % in 2030
Taxi Electrification	0 % in 2010 to 25 % in 2030	0 % in 2010 to 50 % in 2030
Rail Electrification	44 % in 2010 to 48 % in 2030	44 % in 2010 to 60 % in 2030
Heavy-duty Trucks VKT	52,139 km/yr	35,000 km/yr due to improved logistics
Heavy-duty Trucks Fuel Mix	Diesel: 100 % in 2010 to 80 % in 2030 Natural gas: 0 % in 2010 to 20 % in 2030	Diesel: 100 % in 2010 to 50 % in 2030 Natural gas: 0 % in 2010 to 50 % in 2030

Table 2. China's projected passenger and freight road transport vehicle stock, 2010–2030.

millions	2010	2015	2020	2025	2030
Motorcycles	32.2	39.7	45.2	45.2	45.2
Taxis	1.0	1.4	1.9	2.4	2.9
Fleet Cars	11.3	12.0	12.4	11.6	10.6
Private Cars	47.8	103.7	182.3	253.4	321.6
Inter-city Buses	0.8	1.2	1.6	2.2	2.8
Intra-city Buses	0.4	0.5	0.7	0.9	1.0
Mini Trucks	1.7	2.4	2.9	3.2	3.4
Light Duty Trucks	8.4	13.9	19.2	23.1	25.7
Medium Duty Trucks	2.1	2.4	2.8	3.2	3.5
Heavy Duty Trucks	3.6	5.8	8.6	12.7	16.8
Total	109.1	183.1	277.5	357.8	433.4

growing fuel shares for natural gas and electricity. Increases in the number of urban buses, taxis and trucks fuelled by natural gas as well as electric vehicles and rail will contribute to raising natural gas's share of transport final energy demand from less than 1 % in 2010 to 8 % in 2030. At the same time, the fuel share for electricity in the transport sector will remain relatively steady at 3 % as a result of continued electrification in both road and rail.

In terms of transport energy demand by mode, Figure 3 shows that while energy demand was roughly equal between passenger and freight transport modes in 2010, freight transport – specifically road – is expected to grow rapidly over the next fifteen years. By 2030, the energy demand of freight road transport alone will exceed that of all passenger transport modes combined and account for nearly half of all transport energy demand. This is because of substantial growth expected in the demand for freight hauling, including both bulk and final goods, and because freight vehicles travel much longer distances and are substantially less efficient than passenger vehicles. The energy demand of all freight transport will have more than doubled that of passenger transport, with annual demand of 427 Mtoe for freight and only 203 Mtoe for passenger in 2030.

The dominance of freight in transport energy consumption can also be observed in looking specifically at the energy consumption of specific modes of freight and passenger road transport, as shown in Figure 4. Although private car ownership is expected to grow, sedans and SUVs are already relatively efficient in China and thus will not impact energy consumption as much as freight vehicles. Heavy-duty vehicles, on the other hand, will have the largest impact on road transport energy consumption and by 2030, accounting for more energy consumption than all passenger vehicles combined.

TRANSPORT SCENARIO ANALYSIS: ALTERNATIVE TRANSPORT SCENARIO

Compared to the reference scenario, the alternative scenario of accelerated passenger car electrification, reduced heavy-duty truck travel activity and more aggressive fuel switching from diesel to natural gas for heavy-duty trucks results in lower transport final energy demand and CO_2 emissions. As shown in Figure 5, increased electrification and fuel switching can contribute to annual net energy savings that grows from 32 Mtoe in 2020 to 72 Mtoe in 2030, or roughly 10 % reduction from the reference scenario total transport energy demand. This translates into cumulative net reduction of 776 Mtoe of transport final energy demand from 2010 to 2030.

Figure 6 shows the transport energy demand reduction under the alternative scenario of accelerated electrification and fuel switching by mode. The largest transport energy savings under the alternative scenario is from fuel switching and improved productivity (i.e., lowered VKT) of heavy-duty freight trucks, which accounts for 75 % of the annual net savings by 2030. The next largest share of savings – 15 % in 2030 - is from the accelerated electrification of private cars, followed by the electrification of taxis with an 8 % share of the annual net savings in 2030. With rail transport already among the most efficient in the world, few savings are realized with increased electrification of rail passenger and freight transport.

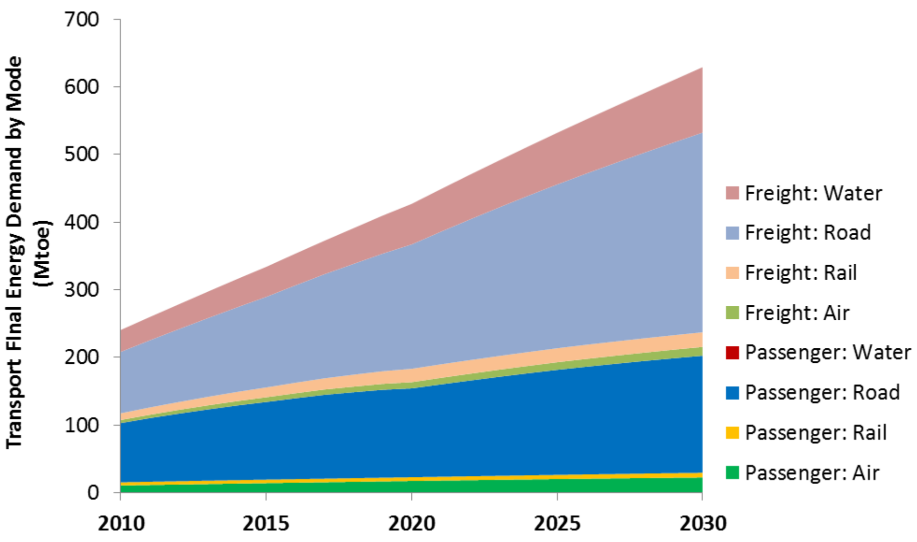

Figure 3. Transport final energy demand by mode, 2010–2030.

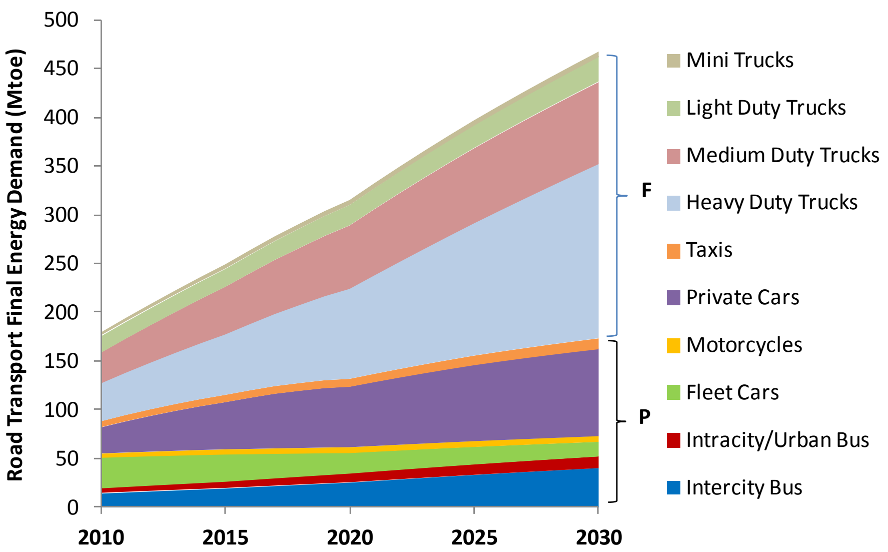

Figure 4. Road transport energy consumption by vehicle type, 2010–2030.

In terms of the specific impacts of electrification and fuel switching on demand for different fuels, Figure 7 shows that the greatest impact will be on reducing diesel demand. By 2030, up to 80 Mtoe of diesel will be displaced by accelerated passenger vehicle electrification and fuel switching of heavy-duty trucks operating with improved logistics by 2030 with cumulative reductions totaling 834 Mtoe. The significant displacement of diesel demand – 21 % of total diesel demand in 2030 – is important given China's reliance on diesel imports. In addition, accelerated electrification will also help displace gasoline on the order of 25 Mtoe per year by 2030. The displacement of oil products, however, is partially offset by increased transport demand for natural gas and electricity, with additional 29 bcm of natural gas and 62 TWh of electricity required under the alternative transport scenario by 2030.

This change in fuel demand under the alternative transport scenario results in net CO_2 reduction, with annual net CO_2 reductions of 109 Mt CO_2 in 2020 and 216 Mt CO_2 in 2030, or nearly 2 % of the national total CO_2 emissions expected in 2030. A total of 2,439 Mt CO_2 can be reduced cumulatively from 2010 to 2030 as a result of the net transport energy savings and displaced fossil fuel demand.

OIL SUPPLY AND DEMAND GAP IMPLICATIONS

China's rising demand for energy to sustain its rapid economic growth and industrialization over the last three decades has made it a net importer of all key fossil fuels, including oil as early as 1996. Since then, China's net import dependency[2] for oil has grown rapidly as seen in Figure 8, with its import de-

2. We define net import dependency as net petroleum imports as a share of total petroleum consumption.

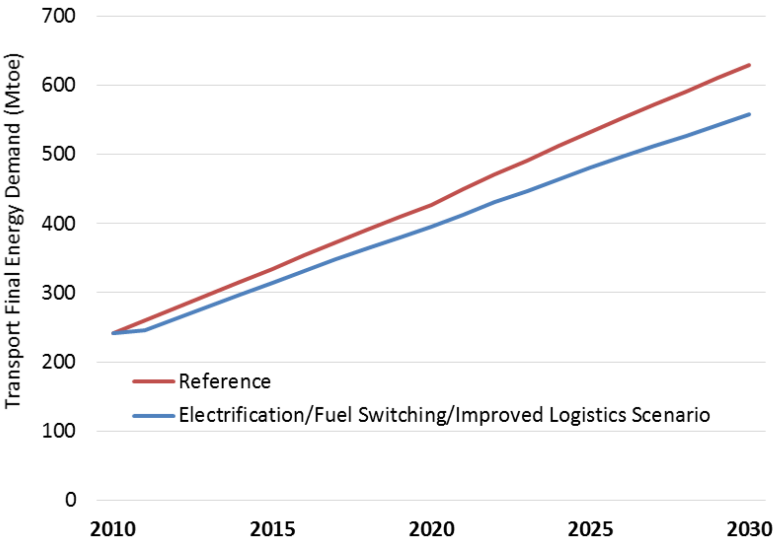

Figure 5. Transport final energy demand by scenario, 2010 to 2030.

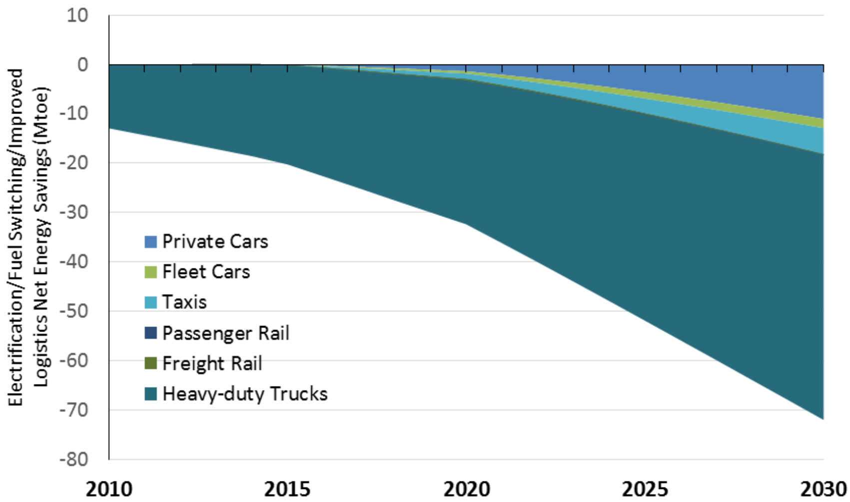

Figure 6. Electrification and fuel switching net energy savings by mode, 2010 to 2030.

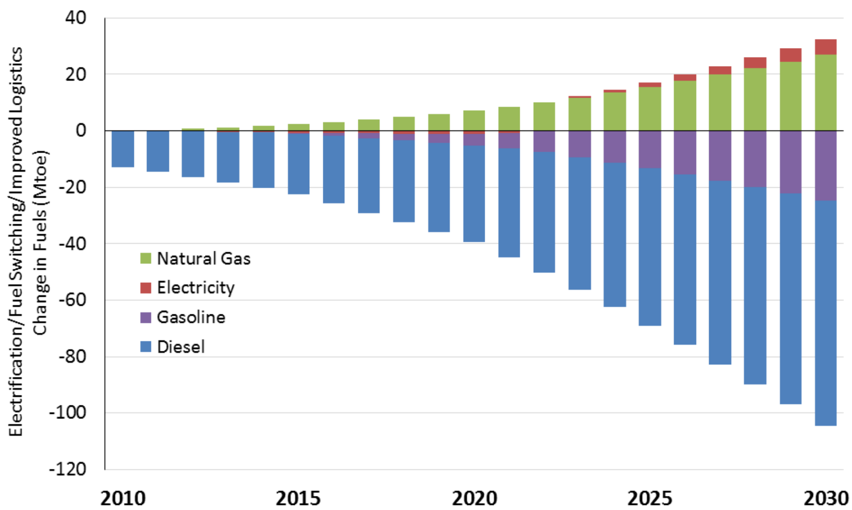

Figure 7. Change in transport fuels due to electrification and fuel switching, 2010 to 2030.

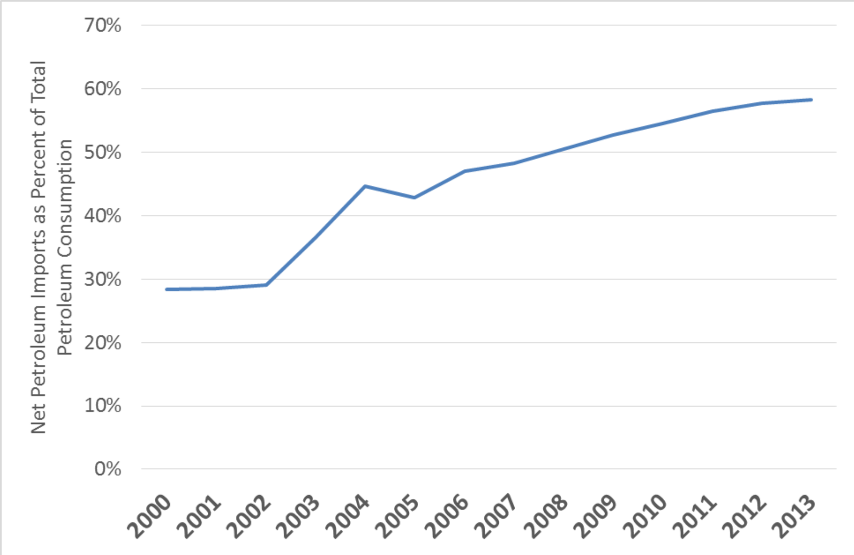

Figure 8. China's Historical Net Import Dependency for Petroleum, 2000–2013. Sources: China's oil consumption data from NBS, 2013. China's crude oil and oil products import data from UN Comtrade database (UN, 2014).

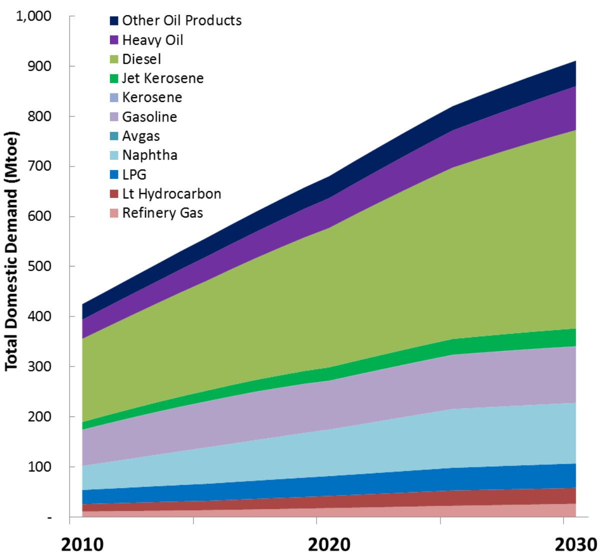

Figure 9. Total domestic Demand for petroleum products, 2010–2030.

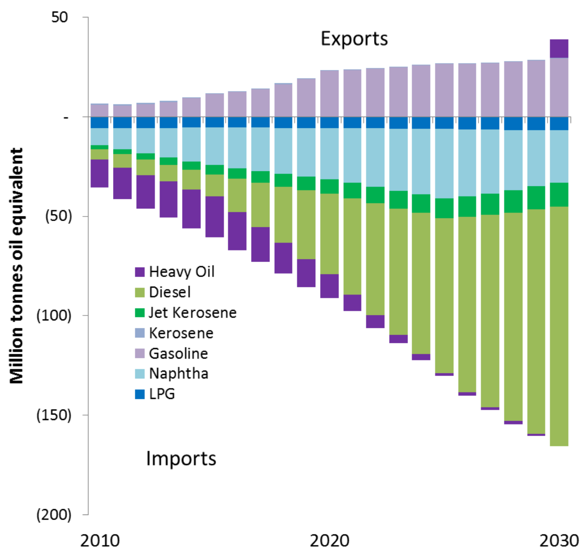

Figure 10. China's major oil products imports and exports, 2010–2030.

pendency doubling from 28 % to 56 % in only eleven years from 2000 to 2011.

In the future, China's net import dependency for oil is expected to continue to rise as national oil demand is projected to grow from 346 Mtoe in 2010 to 570 Mtoe in 2020 and 773 Mtoe in 2030. The growth in oil demand will continue to be driven by the transport sector, which accounted for 52 % of national oil consumption in 2010 and an expected higher share of 57 % by 2030. Driven by the significant volume of freight activity in the transport sector, the largest share of China's oil product demand will be for diesel, followed by gasoline and naphtha for petrochemical use as shown in Figure 9.

In terms of refinery processing capacity and crude oil demand (including domestically produced and imported crude oil), it is assumed effective refinery capacity will be 95 % of aggregate domestic demand. Because of the demand mix, this results in large volumes of both refined product imports, particularly for diesel and naphtha, and exports predominantly of gasoline as seen in Figure 10.

In order to evaluate the oil supply-demand gap given the national oil demand results from the reference scenario of transport development, an oil supply curve was developed for China using a symmetric logistic distribution function to determine possible extraction profiles that accord with the total volume of reserves available for extraction, with maximum extraction levels occurring at about half-way in the depletion of the reserves. These curves were fitted to historical extraction figures from 1949 through 2013. For oil, a high estimate of 114 billion barrels was assumed for the total volume of ultimate recoverable reserves based on Feng et al 2008.

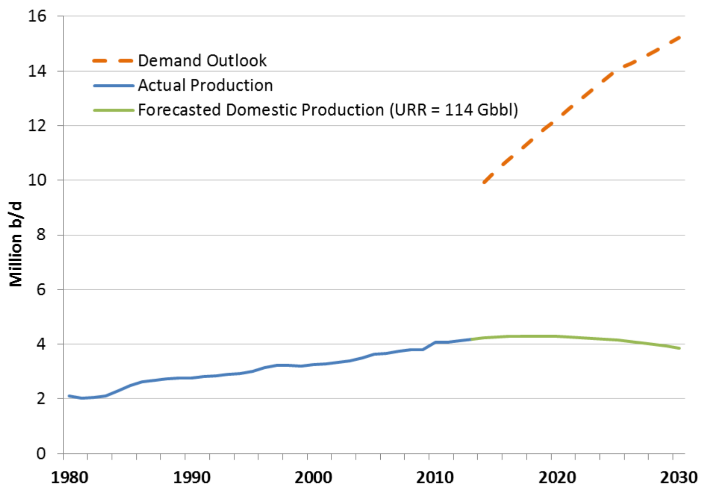

Figure 11. China's historical and projected oil supply and demand.

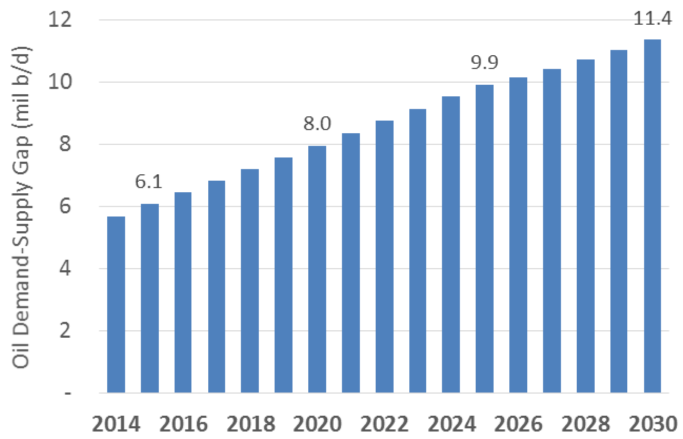

Figure 12. Projected oil supply-demand gap, 2014–2030.

Figure 11 shows that China's crude oil supply is projected to flatten and begin decreasing around 2020 in a scenario where the ultimate recoverable reserves (URR) totals 114 billion barrels, while demand continues to grow rapidly at annual average rates of nearly 3 %. This suggests that the implied supply-demand gap that must be met by imports will nearly double from current level of 5.6 million barrels of oil per day to 11.4 million barrels of oil per day by 2030 as seen in Figure 12. This is equivalent to about one-third of total global crude oil exports today (BP 2014).

Key findings and conclusions

Driven by rising private car ownership and greater road freight demand, the transport sector is expected to be an increasingly important energy end-user for China. In recent years, China has recognized the importance of reining in growth in transport energy demand by adopting various policies to improve efficiency and diversify transport fuel use as well as by setting sector-wide reduction targets for the first time as part of the 12^{th} FYP for 2011 to 2015.

Transport policies adopted in recent years have focused on improving fuel economy through increasingly stringent mandatory fuel economy standards and subsidies for more efficient vehicles. In addition, the Chinese government has also started to promote the development and commercialization of New Energy Vehicles, specifically plug-in hybrid and battery electric vehicles, through pilot demonstration programs and NEV subsidies.

Although NEV production has increased after the launch of the NEV fleet demonstration pilots, many of the demonstration pilot cities were far from meeting their NEV targets. Economic, technological and infrastructural barriers have all limited the success of pilot demonstration programs and pose challenges for rapid increase the future market uptake of NEVs. Key obstacles and challenges that have hampered NEV uptake have included high costs and poor technology choice and performance, lack of a competitive market due to concentrated NEV production and local protectionism, relatively new standardization and inadequate charging infrastructure. The more recent 2012 NEV Development Plan has attempted to address many of these challenges, but the successful electrification of both the private and public fleet will likely require greater policy and technological support as well as shifts in societal and cultural norms.

Looking ahead to 2030, China's fast-growing transport sector will drive final energy demand and particularly the demand for oil and oil products. From an end-use perspective, road transport – particularly for freight – will be the largest driver for future transport energy demand, with heavy-duty trucks alone consuming more energy than all passenger vehicles by 2030. This has significant implications for China's oil demand, as demand for oil and oil products will not only double but also result in an imbalanced strong reliance on diesel imports and excess gasoline production. An alternative pathway of development with greater electrification, diesel to natural gas switch for heavy-duty trucks and improved logistics can help by reducing net final energy demand and CO_2 emissions by 2 % and displacing 21 % of diesel consumption by 2030.

Despite China's recent efforts to improve efficiency and slow energy demand growth, it already faces very high net import dependency of 60 % for oil and could face a significant growing gap in oil through 2030. After taking future supply into consideration, China could still face a potential gap of 11.4 million barrels per day of oil that would need to be met with imports by 2030, or more than a quarter of the total global oil exports today. For oil, China has diversified its import sources but faces challenges with increasingly limited availability of global crude exports and a very high net import dependency ratio. This highlights China's vulnerability to price volatility and supply constraints in the global crude market. In light of the severe net import dependency for oil that could occur even with continued improvements in the transport sector, more aggressive energy efficiency improvements along with fuel switching and electrification are crucial strategies for China to not only meet its rising energy demand and intensity targets, but manage its import dependency and energy security risks.

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Acknowledgments

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